Illinois Department of Transportation
Memorandum

To: ALL BRIDGE DESIGNERS 15.8

From: D. Carl Puzey

Subject: Slab Bridge Design Revisions

Date: December 2, 2015

D. Carl Puzey

Over the past several years the Department has observed atypical cracking patterns in several slab bridges. To study this issue further, an investigation was initiated on a 3 span slab structure with long spans and high skew that had exhibited extensive cracking. It was determined the structure satisfied the current AASHTO design code requirements so a more thorough parametric study was launched. The emphasis of the study focused on the effect of skew and continuity in slab bridges, but it also looked at simple spans, span length, span length ratios, longitudinal force effects, transverse force effects, torsion and shear.

The study findings suggested there are deficiencies in the current AASHTO LRFD Bridge Design Specifications regarding slab bridge design. The Department will request AASHTO to review our findings and consider possible future changes in the design specifications. However, until AASHTO revisions are made, the equations and recommendations in this memorandum shall be used in addition to the AASHTO Code requirements for reinforced concrete design of slab bridges within the following limits:

- Skew Angle ≤ 50°
- 20 ft. ≤ Span Length (ft.) ≤ 56 ft. *
- 24 ft. ≤ Bridge Width (ft.) ≤ 48 ft. **
- 1.0 ≤ Continuous Span Ratio ≤ 1.4
- Transverse reinforcement shall be placed perpendicular to the centerline of bridge. ***

* The Bridge Manual limits slab bridge spans to 40 feet. This limit may only be exceeded for rare circumstances when approved by the Bureau of Bridges & Structures.

** The Bridge Manual permits a maximum slab width of 45 ft. before an open joint is required; although, this may be exceeded if additional computations and detailing account for shrinkage or if staged construction is present.

*** The exception would be on simple span slab bridges where the Department prefers to place the transverse reinforcement along the skew similar to approach slab details. Therefore, when placing reinforcement along the skew, the area of transverse reinforcement determined from the formulas shall be multiplied by $\sec^2$(skew angle).

GENERAL

Primary Longitudinal Reinforcement

The approximate method equivalent strip width for Slab Type Bridges (E), equations 4.6.2.3-1 and 4.6.2.3-2, remains unchanged.

The skew reduction factor (r), equation 4.6.2.3-3, shall be applied to the live load longitudinal force effect. The new equations in this memorandum have been derived accordingly.

Transverse Distribution Reinforcement

The primary recommendations from the study were to help eliminate the atypical cracking patterns through improved transverse reinforcement. This was accomplished by determining a relationship between the longitudinal reinforcement and the transverse reinforcement using a series of beta factors. These factors account for skew, length, width, and continuity as described below. Therefore, in lieu of the AASHTO provisions of Article 5.14.4.1 the following equations shall govern the design and placement of transverse distribution reinforcement.

Edge beam reinforcement shall be investigated according to AASHTO Article 4.6.2.1.4b but any additional reinforcement determined for the edge beam shall not be considered when determining the percentages of transverse reinforcement.

SIMPLE SPANS

Bottom Transverse Distribution Reinforcement

$A_{s(bot,trans)} = \beta_{total(bot)} \times A_{s(bot,long)}$

$\beta_{total(bot)} = (\beta_{base} + \beta_{skew} + \beta_{length} + \beta_{width}) \le \beta_{max}$

where:

$\beta_{total(bot)}$ = factor of main bottom longitudinal reinforcement.
$\beta_{base} = 0.21$
$\beta_{skew} = \tan\theta \times 0.35\,(1 + 0.02(L - 20))$
$\beta_{length} = 0.30 - 0.0075L \ge 0.0$
$\beta_{width} = 0.02\sqrt{(W - 24)} \ge 0.0$
$\beta_{max} = 0.70$
L = span length according to 7th edition AASHTO LRFD Table 4.6.2.2.1-2 (ft.)
W = physical edge-to-edge final width of bridge (ft.)
θ = skew angle (degrees)

Top Transverse and Top Longitudinal Reinforcement

$A_{s(top,trans)} = \beta_{total(top)} \times A_{s(bot,long)}$
$A_{s(top,long)} = \beta_{total(top)} \times A_{s(bot,long)}$

$\beta_{total(top)} = 0.20$

where:

$\beta_{total(top)}$ = factor of main bottom longitudinal reinforcement.

This reinforcement shall not be less than that required for shrinkage and temperature according to LRFD Article 5.10.8.

CONTINUOUS SPANS

Bottom Transverse Distribution Reinforcement

$A_{s(bot,trans)} = \beta_{total(bot)} \times A_{s(bot,long)}$

$\beta_{total(bot)} = (\beta_{base} + \beta_{skew} + \beta_{length} + \beta_{width}) \times 1.1 \le \beta_{max}$

where:

$\beta_{total(bot)}$ = factor of main bottom longitudinal reinforcement.
$\beta_{base} = 0.21$
$\beta_{skew} = \tan\theta \times 0.2\,(1 + 0.02(L - 20))$
$\beta_{length} = 0.32 - 0.0055L \ge 0.0$
$\beta_{width} = 0.02\sqrt{(W - 24)} \ge 0.0$
$\beta_{max} = 0.80$
L = span length according to 7th edition AASHTO LRFD Table 4.6.2.2.1-2 (ft.)
W = physical edge-to-edge final width of bridge (ft.)
θ = skew angle (degrees)

Top Transverse Distribution Reinforcement

$A_{s(top,trans)} = \beta_{total(top)} \times A_{s(top,long)}$

See attached examples for application. Note that in top slab regions where no negative moment exists, the minimum top longitudinal reinforcement and the minimum top transverse reinforcement shall be 20% of the main bottom longitudinal reinforcement.

$$\beta_{total(top)} = (\beta_{base} + \beta_{skew} + \beta_{length} + \beta_{width}) \times 1.2 \leq \beta_{max}$$

where:

$\beta_{total(top)}$ = factor of main top longitudinal reinforcement.
$\beta_{base} = 0.24$
$\beta_{skew} = \tan\theta \times 0.55 (1 - 0.013(L - 20)) \geq 0.0$
$\beta_{length} = 0.12 - 0.0025L \geq 0.0$
$\beta_{width} = \sin\theta \times 0.02 \sqrt{(W - 24)} \times (L / 20) \geq 0.0$
$\beta_{max} = 1.00$
L = span length according to 7th edition LRFD Table 4.6.2.2.1-2 (ft.)
W = physical edge-to-edge final width of bridge (ft.)
θ = skew angle (degrees)

BRIDGE APPROACH SLAB BASE SHEETS

The base sheets for cast-in-place Bridge Approach Slab Details for zero, left and right skews shall be standardized based on these research equations as follows:

Bottom longitudinal reinforcement:	#9 bars @ 5” cts.
Bottom transverse reinforcement:	#8 bars @ 6” cts.
Top longitudinal reinforcement:	#5 bars @ 8” cts.
Top transverse reinforcement:	#5 bars @ 8” cts.

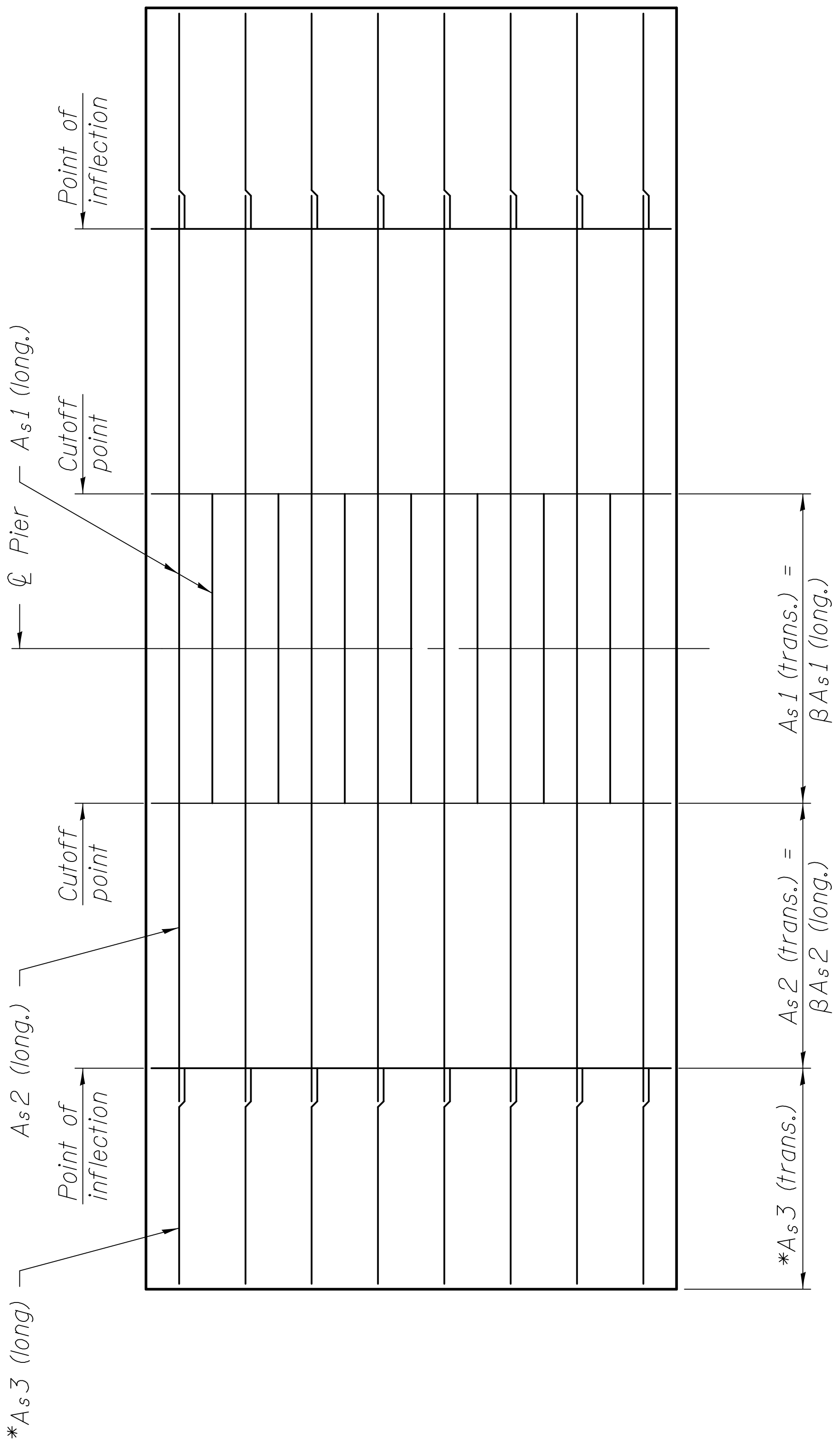
The transverse reinforcement shall be placed along the skew as currently detailed. Revised base sheets are scheduled for a later date to coincide with a complete set of changes on these base sheets, including the latest changes to the Highway Standards for bridge approach pavement connector. The Slab Bridge Design Guide 3.2.11 will also be updated at a later date to reflect the slab design changes from this memorandum.

Implementation

The new equations for slab design and the standardized reinforcement for Bridge Approach Slabs are encouraged to be implemented immediately on all applicable projects where plans have not been approved but they shall be effective for projects with TS&L’s approved after January 1, 2016. Please direct questions to Gary Kowalski of the Policies, Standards and Specifications Unit at (217) 785-2914.

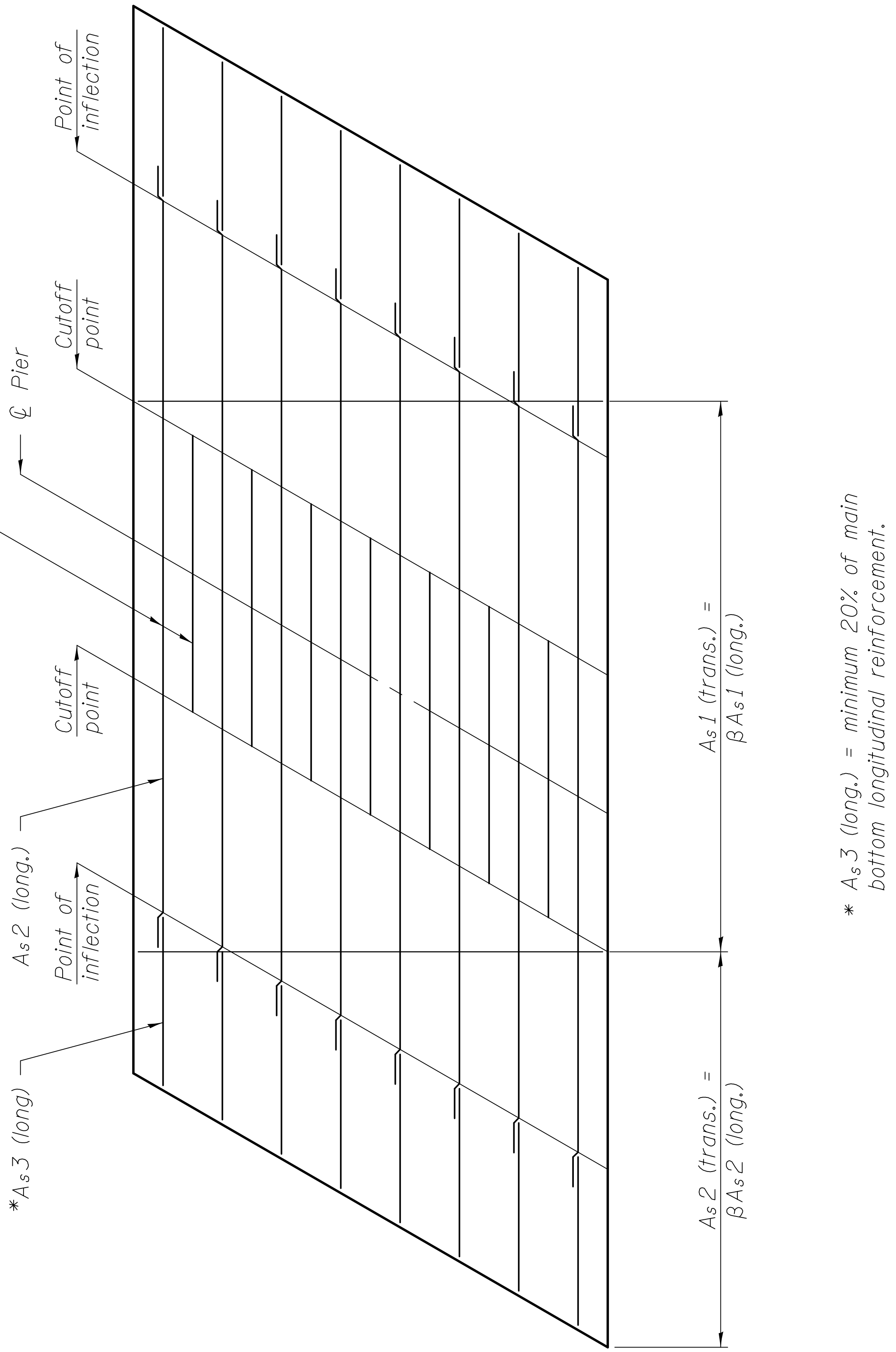
Attachments

KLR/kktABD15.8slabbridge-20151202



$*$ A_s3 (long.) and A_s3 (trans.) = minimum 20% of main bottom longitudinal reinforcement.

TOP OF SLAB
REINFORCEMENT - NO SKEW



TOP OF SLAB
REINFORCEMENT - SKEWED